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Experimental Investigation of the Effects of Antenna Pointing Errors on Range Delays (Part II)

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This article presents new S-band test data obtained from an experimental study of the effects of antenna pointing error on range delays. The tests involved the use of the 26-m antenna at DSS 42, the collimation tower, and the Mu-2 Ranging System.

The results showed that when the antenna offset angles from boresight were less than the 3-dB points on the main beam, the worst case range changes were less than ±7 cm with a measurement precision of about ±1.5 cm. These results represent an improvement factor of 2 over previously reported results.

I. Introduction

A possible source of error on the measurement of time delays for ranging and VLBI is the change in time delays occurring when the antenna pointing changes from boresight (on target) to an angle offset from boresight. An offset from boresight can occur if the antenna pointing system is inaccurate, or when an error has been made in locating the target boresight position, or when using conical scanning.

An experiment involving a collimation tower and Mu-2 Ranging System was previously performed at DSS 42 (Ref. 1). The results indicated that the change in range could be as large as ±13 cm when the 26-m antenna was purposely pointed off target but the offset angle was within the 3-dB points of the main beam. The error bars associated with that test indicated that some of the changes could be due to residual calibration errors, drift, and noise.

This article presents new results of the antenna pointing experiment involving the collimation tower and Mu-2 Ranging System at DSS 42. Very little theoretical or experimental data currently exists on the effects of antenna pointing errors on time delays. The new test data represents an improvement factor of 2 over the previously reported test data and therefore should be documented.

II. Test Setup and Procedure

The test setup consisted primarily of (1) a 2.44-m (8-ft) diameter parabolic antenna with a zero delay device installed on top of the DSS 42 collimation tower and (2) a 20-kW transmitter, a 26-m antenna, the Mu-2 Ranging System, and all of the tracking hardware and software normally used for station delay calibration and spacecraft tracking.

Significant parameters to note for this test were Channel 18 test frequencies (2114.676 MHz uplink and 2296.481 MHz downlink), 15-kW transmitted power, RCP polarization, and the Mu-2 Ranging System set for 1-MHz ranging code, 30-sec DRVID integration, and 3-dB carrier suppression.

The basic test procedure was described in detail in Ref. 1 and will not be repeated here. The improvements in test procedure to obtain data for this article were as follows:

(1) Increase the number of closures back to boresight so that an accurate drift curve could be established and more accurate corrections could be made for drift.

(2) Insert a calibrated attenuator into the 182-MHz line at the collimation tower. The attenuator was adjusted at each offset angle to maintain a fairly constant downlink signal level. This procedure resulted in a smaller and less significant correction needed to account for range delay changes as a function of received signal levels.

(3) Increase the integration times for the DRVID[1] data at weaker signal levels so that standard deviations were nearly the same at all boresight offset angles.

III. Test Results

Figure 1 shows the improved test results that were obtained with the new test procedures. The test results were corrected for changes in range delays due to signal level changes and also for drift in range delays with time. The data reduction procedure was to (1) obtain a signal level versus range correction curve by a weighted least squares method (see Ref. 1), (2) correct range data for signal level changes, (3) perform a weighted second order least square curve fit to the boresight (zero offset angle) data versus time to obtain a drift curve and (4) make corrections for drift. The one-sigma error limits shown in Fig. 1 are standard deviations of the mean (or standard error) which include errors due to measurement dispersion, errors in the signal level calibration curve, and errors in the drift correction curve. It can be seen that the total standard error is typically about 1.5 cm over the entire curve. In the previously reported experiment, the standard error was typically larger than 10 cm for offset angles greater than 0.16 degrees.

A more careful measurement involving the use of a calibrated attenuator at the collimation tower led to the result that the 3-dB points for the 26-m antenna were closer to 0.18 degree than the 0.15 degree reported in Ref. 1. The value of 0.18 degree agrees well with a 0.19 degree calculated average value for uplink and downlink frequencies of 2114.676 MHz and 2296.481 MHz, respectively. The new power pattern or boresight curve shown in Fig. 1 was obtained by taking one-half of the total measured signal level changes versus offset angles. The factor of one-half accounts for the fact that a signal level change on the uplink signal occurs due to offset angle and approximately the same change occurs on the downlink signal when it returns from the collimation tower back to the 26-m antenna.

Examination of the range change data in Fig. 1 reveals that the maximum changes in range occurring within the 3-dB points are ±3 cm for elevation angle offsets and ±7 cm for azimuth angle offsets. The differences in azimuth and elevation range change curves are believed to be due to differences in ground multipath. It was previously thought that the difference in the two curves could be due to the quadripod support multipath. However, a further study showed that the quadripods are oriented close to 45 degrees with respect to the DSS 42 collimation tower vertical. Since the quadripod geometry is nearly the same for the two offset scan planes, quadripod multipath does not provide an explanation for the differences in the two scan plane results.

The test data has been analyzed for measurement error, but no further corrections have been made on the data. If the normal DSN procedure for correcting for declination angle changes were made for this test, the corrections would have been less than ±1 cm.

Further analytical work needs to be done to confirm that antenna pointing errors are as small as was observed in these tests. Experimental work using VLBI techniques also needs to be done to determine if antenna pointing errors have negligible effects on VLBI measurements.

IV. Conclusions

An improved experiment was performed at DSS 42 to determine the effects of antenna pointing errors on range delays. It was found that when the 26-m antenna was scanned off target for antenna angle offsets within the 3-dB points of the main beam, the worst case range changes were less than ±7 cm with measurement uncertainties of about ±1.5 cm. These results represent an improvement factor of 2 over previously reported results.

[1] DRVID is an acronym for Differenced Range versus Integrated Doppler. When doppler is disabled as was the case for this test, the DRVID data becomes group delay change only.

Acknowledgments

The experimental results presented in this article are a tribute not only to the Mu-2 Ranging System, with its 1-MHz range code, but also a tribute to personnel at DSS 42 who obtained the test data. It should be mentioned that the author of this article contributed suggestions for the improved test procedures and performed the measurement error analysis of the experimental data, but the initiative, testing, and much of the primary data reduction were provided and accomplished by Alan Robinson and other personnel at DSS 42.

Reference

1. Otoshi, T. Y., and Taylor, T. T., "An Experimental Investigation of the Effects of Antenna Pointing Errors on Range Delays," in *DSN Progress Report 42-53*, Jet Propulsion Laboratory, Pasadena, Calif., Sep. 15, 1979, pp. 141-147.

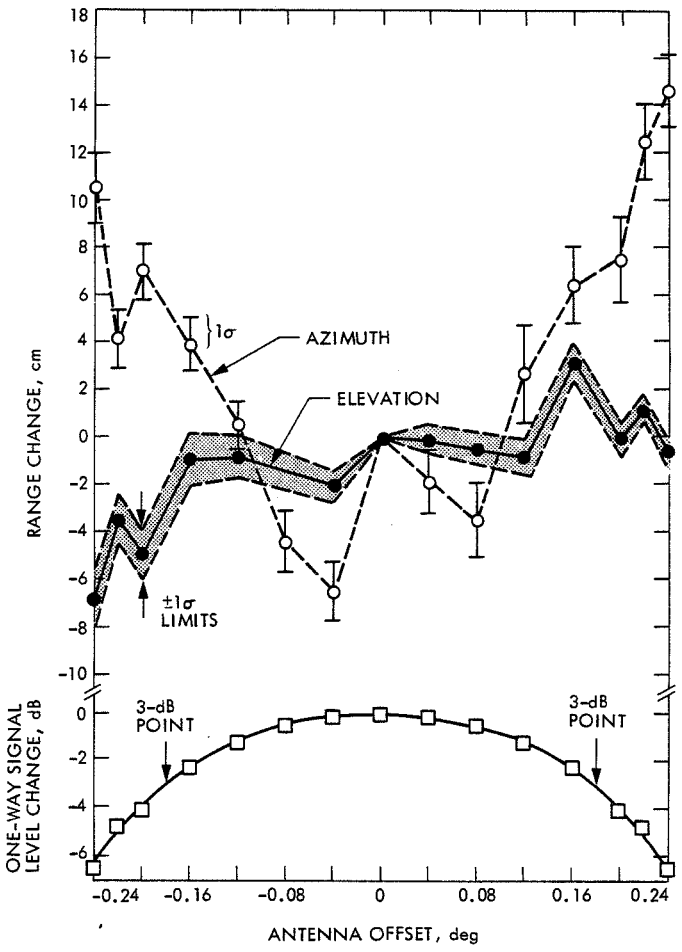

Fig. 1. Range delay changes versus elevation and azimuth angle offsets from boresight (tests performed at DSS 42 on 26-m antenna on 1979 Day of Year 225)